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Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI & FPAR

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The objective of our effort is to develop a radiative transfer based synergistic algorithm for estimation of global leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR). The algorithm consists of a main procedure that exploits the spectral information content of MODIS measurements and the angular information content of MISR measurements to derive accurate estimation of LAI and FPAR. Should this main algorithm fail, a back-up algorithm is triggered to estimate LAI and FPAR using vegetation indices. Both algorithms are capable of executing in MODIS-only or MISR-only mode, should cloud contamination, data frequency and spatial or temporal resolution requirements hinder a joint MODIS/MISR mode of operation. A comprehensive three-dimensional radiative transfer model for vegetated surfaces is utilized by both the algorithms to connect remote observation to surface variables of interest. The algorithm requires a land cover classification that is compatible with the radiative transfer model used in their derivation. Such a classification based on vegetation structure was proposed and it is expected to be derived from the MODIS Land Cover Product. Therefore, our algorithm has interfaces with the MODIS/MISR surface reflectance product and the MODIS Land Cover Product. The following is a brief description of our activities during the first half of 1997 (July through December).

1. Our algorithm is based on a representation of the canopy-leaving radiance as the sum of solutions of two independent sub-problems. The first describes photon interactions with the vegetation canopy when soil reflectance is zero. The second describes the radiative regime generated by an anisotropic and heterogeneous source located at the canopy bottom. A special technique was developed and implemented to store the solutions of these problems in LUT in a very compact form. Canopy reflectance models are used to create LUT.

2. In spite of the diversity of canopy reflectance models, their direct use in an inversion algorithm is ineffective. In the case of biomes 2-6, for example, the interaction of photons with the rough and rather thin surface of the tree crowns and with the soil in-between crown openings are the most important factors causing the observed variation in the directional reflectance distribution of plant canopies. Many canopy reflectance models essentially use this property. As a result, they are only slightly sensitive to the within-canopy radiation regime. Mathematically, this assertion is based on the fact that a rather wide family of canopy radiation models is equivalent to the solution of the transport equation which includes a non-physical internal source. Within such of a model, therefore, the radiation absorbed, transmitted and reflected by the canopy is not equal to the radiation incident on the canopy. On the contrary, just the within-canopy radiation regime is very sensitive to the canopy structure and, as a consequence, to LAI. The within-

canopy radiation regime also determines the amount of solar energy absorbed by tree. Ignoring this in canopy radiation models leads to a big number of non-physical solutions when one inverts a canopy reflectance model. In order to avoid such solutions in our algorithm we introduce weights defined as the ratio of the BRF (Bi-directional Reflectance Factor) to hemispherically integrated reflectance. This allows us to convert measured BRF to DHR (Directional Hemispherical Reflectance) which, in turn, can be expressed via canopy transmittance and absorptance, which are elements of LUT. Thus, our algorithm is now sensitive both to the factors determining the directional reflectance distribution of plant canopies and to the within canopy radiation regime. The LUT with weights as a function of sun-view geometry, LAI and wavelength was created.

3. In spite of the essential reduction of possible canopy representatives by introducing the vegetation cover classification as well as implementing the technique described above, the inverse problem still allows for multiple solutions. In order to estimate the most probable solution, a relationship between canopy reflectances, their uncertainties and LAI was established. This relationship is expressed in terms of a LAI distribution function, which possesses properties similar to the cumulative distribution function used in probability theory. It allows us to express a desired LAI as the expectation of LAI with respect to the LAI distribution function. This technique can use all information provided by the MODIS and MISR instruments and is sensitive both to their qualitative and qualitative characteristics.

4. Given MODIS and/or MISR data, it may be the case that the LAI algorithm admits a number of solutions, covering a wide range of LAI values. When this happens, the retrieved reflectances are said to belong to the saturation domain, being insensitive to the various parameter values characterizing the biome type. Under this condition, the LAI distribution function which describes the number of times a solution has a particular LAI value will appear flat over the range of LAI, illustrating that the solutions all have equal probability of occurrence. The saturation domains were precompute and stored in the LUT. Now the algorithm is able to specify this situation. We assign sign "-" to QA if the measured data are in the saturation domain. Inclusion of the mines sign in QA means that a solution, LAI, was found, but the signal likely belongs to the saturation domain and value of LAI from a rather broad interval (specified in the LUT) must be considered as a true solution with equal probability.

5. A new version 2 (Prototype 2) of algorithm which realizes the above described techniques was prepared. The MISR LAI/FPAR ATBD was completely rewritten and sent to JPL. The algorithm code was delivered both to the MISR project at JPL and to the University of Montana (our MODIS collaborators). Version 2 of the MODIS LAI and FPAR algorithm is currently being developed by the MONTANA MODIS investigators.

6. A description of our approach was prepared as a contribution to a collaborative MODLAND paper for TGARS.

7. Two papers containing a detailed description of the synergistic LAI/FPAR retrieval algorithm and its MISR-only version were submitted for publication in the EOS-AM1 special issue of JGR.

8. During the next quarter, we will continue work on the implementation of our algorithm, with aim of prototyping the main algorithm using available remotely sensed data set (AVHRR, POLDER, LANDSAT and SEAWIFS).